15063

OPSEC REVIEW CERTIFICATION
(AR 530-1, Operations Security)

STATEMENT BY REVIEWING ORGANIZATIONS

"I am aware that there is foreign intelligence interest in publicly available information. I have sufficient technical expertise in the subject matter to certify that it is appropriate to release this information to the public, because there are no operational, legal, or security reasons for withholding its release. Information that was given a previous OPSEC Review, does not require a second review, unless the original infomation has been changed."

DESCRIPTION OF INFORMATION TO RECEIVE OPSEC REVIEW:

Title/Description of Item to be released: "Use of Modeling & Simulation to Recieve New Design Acceptance

(Step 1) Author/Originator: Steven Schultz **Organization:** TARDEC **Phone:** 586 574 6676

Forum where this information is to appear: SAE 2006

Purpose of release: Engineering Paper **Anticipated date of release:** ~~Oct 2005~~ Nov 10, 05

Product format (Circle): Article, Briefing, Web site, Equipment display, Video tape, Brochure, CD

(Step 2) Tech Reviewer: Steve Schultz **Grade:** NH-3 **Position:** Mech. Eng.

Signature: [signature] **Date:** 10/27/05 **Phone:** 586 574 6676

(Step 3) Gov't Supervisor: Paul Decker **Grade:** NH-4 **Position:** Mech Engr

Signature: Paul Decker **Date:** 10/31/05 **Phone:** 586 574 7803

(Step 4) Gov't Contracting Officer (if applicable):

Signature: **Date:** **Phone:**

(Step 5) Legal Office Reviewer (if applicable): Luis Miguel Acosta

Signature: Luis Miguel Acosta **Date:** 8 NOV 05 **Phone:** 574-8682

(Step 6) G2/G3 (OPSEC Officer): DENNIS CAREY **Position:** OPSEC OFFICER

Signature: Dennis M. Carey **Date:** 7 NOV 05 **Phone:** 586.574.5604

(Step 7) Public Affairs Reviewer: ERIC EMERTON **Position:** GS

Signature: Eric Emerton **Date:** 7 Nov 05 **Phone:** 45663

	Author	Tech Reviewer	Gov't Supervisor	Gov't Contract Officer	Legal	G2/G3 (OPSEC Off)	Public Affairs
a. Concur for Public	SS 10/27/05	SS 10/27/05	X			D 7 Nov 05	[initials]
b. Concur for Public Release w/comment					LMA *		
c. Nonconcur							

Initial and date in appropriate box

a. Recommend approval for public release, distribution is unlimited (Distribution A).
b. Recommend approval for public release subject to changes as noted or attached.
c. Do not recommend public release.

* Author agreed to remove Copyright Notice & understands that as a Governmental Work, no copyright exists for this Article! LMA

STA 7114-E Rev 15 Jun 04

Previous editions obsolete

06M-443

Use of Modeling and Simulation to Receive New Design Acceptance

Steven Schultz
US Army RDECOM TARDEC

ABSTRACT

The U.S. Army's Stryker vehicle was in need of a design upgrade on one of its components. A newly designed hydraulic reservoir was tested and analyzed on a component level to gain acceptance to be used in the vehicle. All of this was done using modeling and simulation to conduct a fatigue analysis and component testing without putting any unnecessary miles on the entire vehicle system. This paper will follow the process and successes associated with using modeling and simulation methods to aid in getting this component fielded.

INTRODUCTION

The Army's Stryker family of vehicles has seen success on the proving ground and in the field. When a new component or redesign is required, it is not always necessary to re-test the entire vehicle on a system level. Sometimes it is possible to test new designs on a component level. Such was the scenario when a new hydraulic reservoir was needed to replace the original.

The original hydraulic reservoir was seen to experience structural failure modes along its weld lines when subjected to rigorous terrain conditions. A new design prototype was developed with stronger welds, new material, and overall increased integrity. Under current Army practices, the new reservoir would have to be installed into the Stryker vehicle and tested on proving grounds at the system level. In testing in this manner, unnecessary system level vehicle miles, proving ground track time, and added stress is added to the entire vehicle. In such a situation as this, a component level test can provide as reliable results without exposing the entire vehicle to the rigors of the proving ground. It should be noted, however, that a component test is not always the best solution. There are many unknown possibilities that may only become apparent when the vehicle is exposed to testing at the system level.

At the system level, all vehicle components may interact with each other in some way and give a true state of the vehicle. The hydraulic reservoir in believed to be a candidate for component testing because it is possible to provide a comparison between the new and old designs showing an improvement in one over the other. Incorporating the new reservoir will also not require other system components or functions to be modified.

As a note, if accepted, this component level test process for the hydraulic reservoir will be the first occurrence of which a vehicle component has been evaluated and analyzed to gain field approval without being subjected to full in-system vehicle test miles for an Army combat vehicle. The testing is to be conducted at the Army's Aberdeen Proving Grounds under the expertise and supervision of Aberdeen Test Center's and Army Materiel Systems Analysis Activity's (AMSAA) engineers. The Program Manager Stryker Brigade Combat Teams and Army Evaluation Command have final approval of any test results and outcomes. The United States Army's Tank Automotive Research, Development and Engineering Center (TARDEC) is overseeing the analysis and testing in support of the Program Manager and will act as the accrediting authority leading toward a final design recommendation.

MAIN SECTION

The following explanation will describe the method and approach followed to analyze the newly designed hydraulic reservoir. The Analytical Analysis and Component Test Schedule sections will show the benefits and approval for why component level testing is a successful approach for replacing the originally designed hydraulic reservoir with the newer design. If the results are favorable, the outcomes of these efforts should show the new design is an improvement over the original.

ANALYTICAL ANALYSIS

Modeling methods can be applied to the reservoir analysis to reduce both time and cost as in-vehicle field testing might not always be available. Using modeling and simulation techniques can quickly provide a solution to many engineering problems. Comparing the two designs of hydraulic reservoir through a fatigue analysis for reliability is an instance that demonstrates the benefits of using modeling and simulation as it does not

require the availability of a Stryker vehicle to come up with the information to support a design decision.

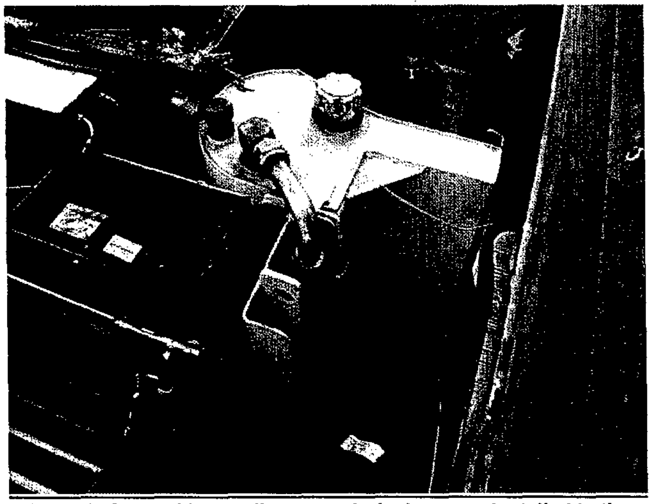

Figure 1: Original hydraulic reservoir design seen installed in the Stryker vehicle.

Calculating Fatigue Predictions

To begin the process of comparison, load histories and ride field data was collected from a number of tests that were conducted on the original reservoir while it was in the Stryker vehicle. This data was required to conduct a modal analysis to determine the failure shapes of the original reservoir. The results from this analysis located the significant modes between the zero and 500Hz range as best as possible considering the reservoir's complex construction of baffles and weld lines. The next step was to develop a finite element analysis (FEA) model from a CAD drawing of the reservoir. This FEA representation modeled the reservoir's sheet metal structure as simple QUAD8 shell elements of a uniform 2mm thickness. Using dynamic modeling tools (Virtual.Lab Motion), the FEA model was incorporated into an existing Stryker multi-body dynamics model.

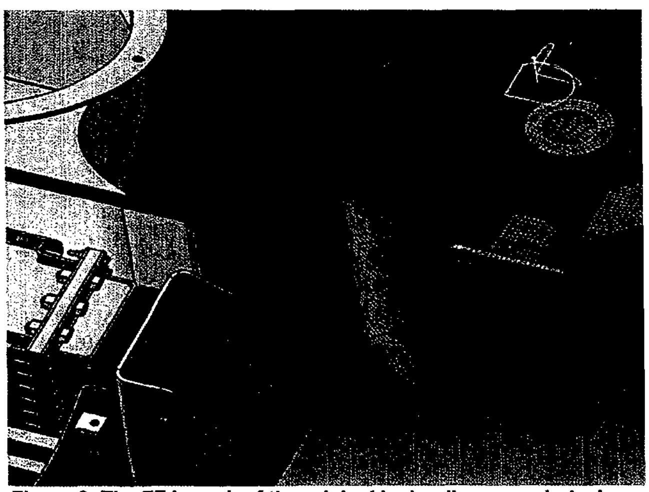

Figure 2: The FEA mesh of the original hydraulic reservoir design.

The reservoir was connected to the vehicle model and constrained at the appropriate connection points that exist in the actual vehicle. The reservoir's hose connections and internal reservoir fluid were also taken into consideration as mass and stiffness were added to the model to give a more realistic representation of the loading the actual reservoir would experience. In this manner, the FEA model was allowed to maintain its flexible properties and capture the forces and displacements as the dynamic model transverses a set of virtual terrains.

Now that a flexible body reservoir was connected to a dynamic model of the Stryker vehicle, the combined models were executed over a suite of digital proving courses; 6" Washboard, 10" Halfrounds, Belgian Block course, and Perryman 3. From the results of the analysis, it was determined that the 10" Halfround terrain produced the most damaging effects to the original reservoir design. The FEA results were analyzed and the primary mode shapes were isolated. The combination of all modes describes the universal motion of the reservoir but for our study, only the most dramatic were used in determining the reliability of the original design. From these key modes, the resulting stresses were calculated and compared against known material property values on an S-N curve. The S-N curve is unique to each material and when component stresses are available, a number of cycles can be estimated to determine the amount of reoccurring stimulus until fatiguing failure is reached. Estimating the number of cycles for the given stress loading provided us with a reliability estimate based on the material of the original reservoir that could be predicted to occur over the component's life cycle. This estimate of time until failure life will be compared to the newly designed reservoir's results to see if any improvement was made due to changes implemented in the new design.

The analysis of the new design hydraulic reservoir was held to the same framework as the process previously done for the original. A CAD and FEA model of the new reservoir was constructed noting the design changes and new material properties. The new reservoir design was constructed from a different grade of aluminum that is slightly denser and having equivalent stiffness. This new FEA model was then attached to the same vehicle dynamics model of the Stryker and ran over the same courses. All other vehicle properties and assumptions remained unchanged. The results gained from the new hydraulic reservoir over the 10" Halfround course, again the most damaging, produced new failure modes. These new failure modes were used to calculate a life estimate and the new reservoir was seen to have a substantial increase in fatigue life prediction.

Validation of the Analytical Results

The method described above takes into account sound physics and accepted engineering approaches. However, whenever a computer model is used to recreate a real world event, several assumptions must be made. Although this is a valid engineering study, there is always the possibility that actual physical testing

may actuate some modes that were unseen in the computer predictions and this analysis should not serve as a replacement for physical durability testing. The results of these analyses for both hydraulic reservoir designs take into account the same assumptions and methods and thereby a good comparison should be able to be drawn between them. The conclusions show that analytically the new design of the reservoir outperforms the original in fatigue life.

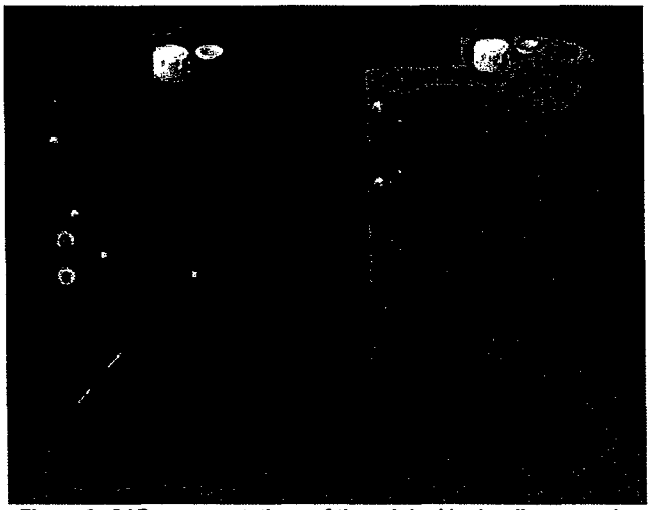

Figure 3: CAD representations of the original hydraulic reservoir (left) and the newly designed reservoir (right).

COMPONENT TEST SCHEDULE

In order to receive the best engineering information on how well the new reservoir compares to the original design, the two reservoirs are to be subjected to a physical component-level test. Both reservoirs will be instrumented on a shaker table experiment to determine the number of cycles that they can withstand before a failure occurs. The vibrations induced through the shaker table should be enough to recreate any damage that may occur in a field test environment. The test will apply similar stress to locations throughout the reservoir structure and its weld lines. The test will conclude after both reservoir designs witness the first signs of leakage failures.

The shaker table experiment will provide additional design comparison information to assist in the final judgment of the newly designed reservoir's performance. For the laboratory shaker table test, unique mounting fixtures must be fabricated to best recreate the actual in-vehicle mounting connections. As this is a component test, the best comparable results to the field will best be obtained by recreating the actual in-vehicle conditions as best as possible. Both reservoirs will be tested side-by-side with hoses and mounting brackets attaching them to the test table. The reservoirs will be filled with an appropriate fluid to give the most realistic recreation of the actual environment.

Instrumentation attached to the original hydraulic reservoir will control and monitor the inputs to the shaker table test. Data collected from proving ground durability tests from the original reservoir was selected to provide inputs that correspond to the most rigorous and damaging terrains. Both the original and newly designed hydraulic reservoirs will be subjected to the same vibrations and monitored until failure occurs to both components. The inputs for the shaker table test are representative of the environment from the mission profile and the new reservoir will need to withstand this level of harshness.

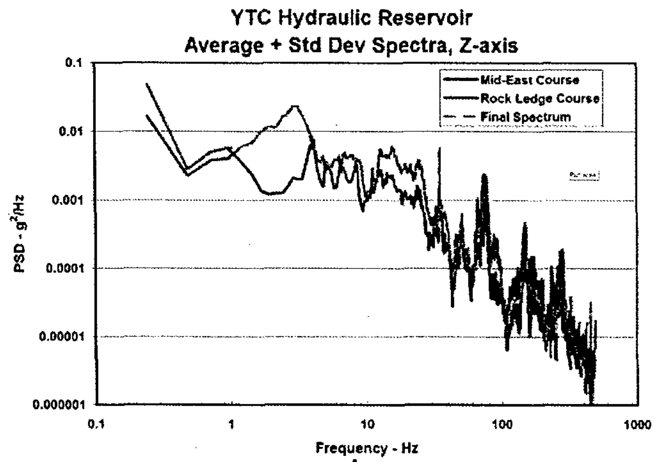

Figure 4: The shaker table inputs were composed of data collected from the most damaging field courses.

CONCLUSION

By combining modeling and simulation methods and component level testing, it is possible to evaluate design options based on engineering fundamentals. As with the new hydraulic reservoir design, engineering information can be gathered to support making a design decision without the need for putting additional miles on a vehicle in a proving ground setting. New components such as the hydraulic reservoir can be shown to exhibit an improvement in reliability through such methods as computer modeling and shaker table testing. Conducting analyses such as these, Army engineers can provide the necessary data and support to help the program managers qualify new components quickly and allow vehicles to be used for other purposes.

Based on the outcome from the shaker table results, information from both the analytical fatigue analysis and durability results will be used to support a decision to incorporate the new hydraulic reservoir design into the Stryker vehicle. If the process proves successful, this method could drive an increase in using modeling and simulation approaches for similar engineering decisions.

At the time this paper was submitted, the shaker table test was awaiting finalization on fixture mount fabrication. Once these mounts are finalized, they will be used to hold the reservoir specimens to the shaker table and under the guidance of Aberdeen Test Center they will be tested until a failure leak is seen to occur. Hopefully, the results of the test will correlate and

support the findings received from the dynamic and finite element fatigue study. The results from all analysis will be reported to the Stryker program managers' to make a final decision and develop a path forward.

ACKNOWLEDGMENTS

The author would like to acknowledge the engineering contributions and support of both the U.S. Army Materiel Systems Analysis Activity (AMSAA) and LMS Engineering.

REFERENCES

1. Stryker Hydraulic Reservoir Fatigue Analysis. LMS Engineering, Final Report. 2005

CONTACT

Steven Schultz is a member of TARDEC's Analytical Simulation Team for the National Automotive Center. His educational background includes a degree in mechanical engineering from the University of Michigan and a master's degree in automotive engineering from Lawrence Technological University. He specializes in military vehicle modeling and conducting virtual test scenarios with these models. He can be contacted at steve.schultz@us.army.mil.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

RDECOM: Research, Development and Engineering Command.

TARDEC: Tank Automotive Research, Development and Engineering Center.